

## Is the Power Density of Large Offshore Wind Farms Limited?

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# Is the Power Density of Large Offshore Wind Farms Limited?

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# Motivation

Adams and Keith, 2013:

**“The results suggest that the maximum energy that can be extracted by turbine arrays at these scales is about  $1 \text{ W m}^{-2}$ .”**

# Adams and Keith, 2013

Adams and Keith, Are global wind power resource estimates overstated? (2013)

## Method

- Weather Research & Forecast (WRF) model
- Wind farm parametrisation from Adams 2007 (Turbine drag + TKE)

Simulations over the Great plains in winter/summer 2006

## Power density estimation in function of:

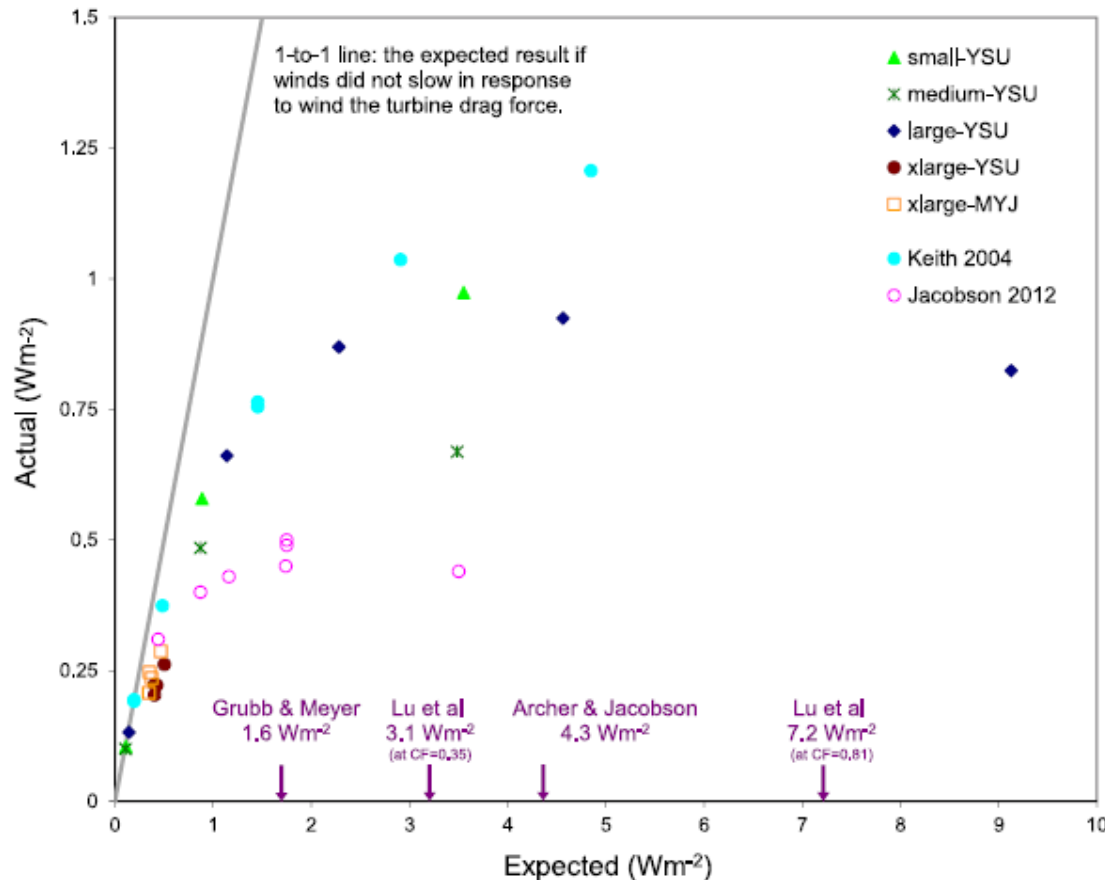
- 1) Wind farm size  $10^3 - 10^5 \text{ km}^2$
- 2) Turbine (2 MW turbines) density  $0.25 - 16 \text{ km}^{-2}$

## Runs with and without wind farms to predict:

- Actual power density  $P_a$  (wake effects)
- Expected power density  $P_e$  (no wake effects)

# Adams and Keith, 2013

Comparison between Expected and Actual power density gives:



Limit:  $P_a \sim 1 \text{ W m}^{-2}$

**Horns Rev I ( $20 \text{ km}^2$ ) has a measured power density:  $3.98 \text{ W m}^{-2}$**

**This would mean:** That the power density of large wind farms is only 25% of that from regular wind farms

# Was the analysis from Adams and Keith 2013 complete?

Does the power density converge to  $1 \text{ W m}^{-2}$  for different climates?

**Experiment:** WRF simulation for:

- 3 wind farm parametrisations
- 2 wind farm sizes
- 3 climates

## Wind farm parametrisations:

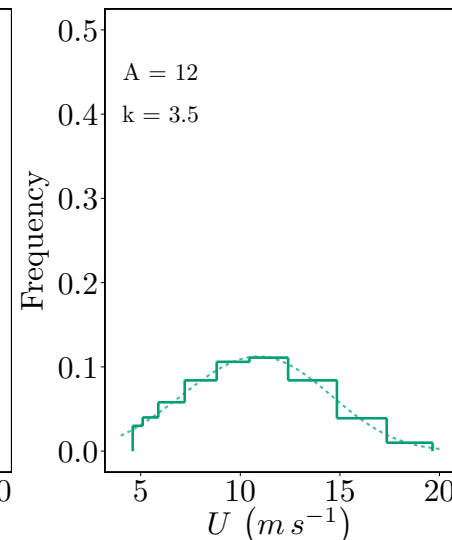
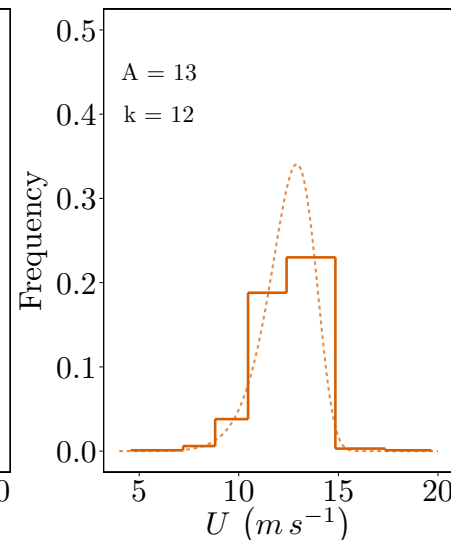
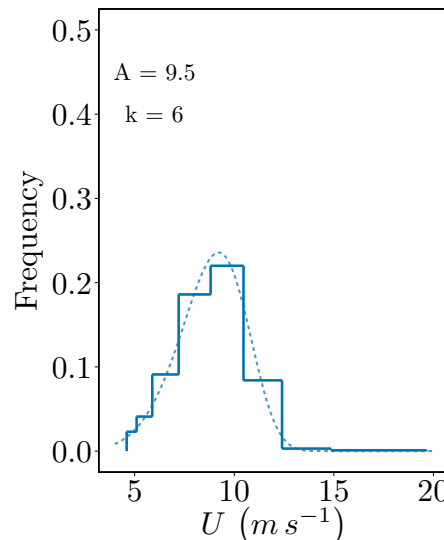
- Explicit Wake Parametrisation (Volker et al. 2014)
- WRF-WF scheme (Fitch et al. 2013)
- ROTOR-DRAG scheme: local drag only

## Rectangular Wind farms (Nominal power density $6.4 \text{ W m}^{-2}$ ):

- 2MW X 100
- 2MW X 3.600

## Wind Climates:

Obtained from 9 idealised case simulations

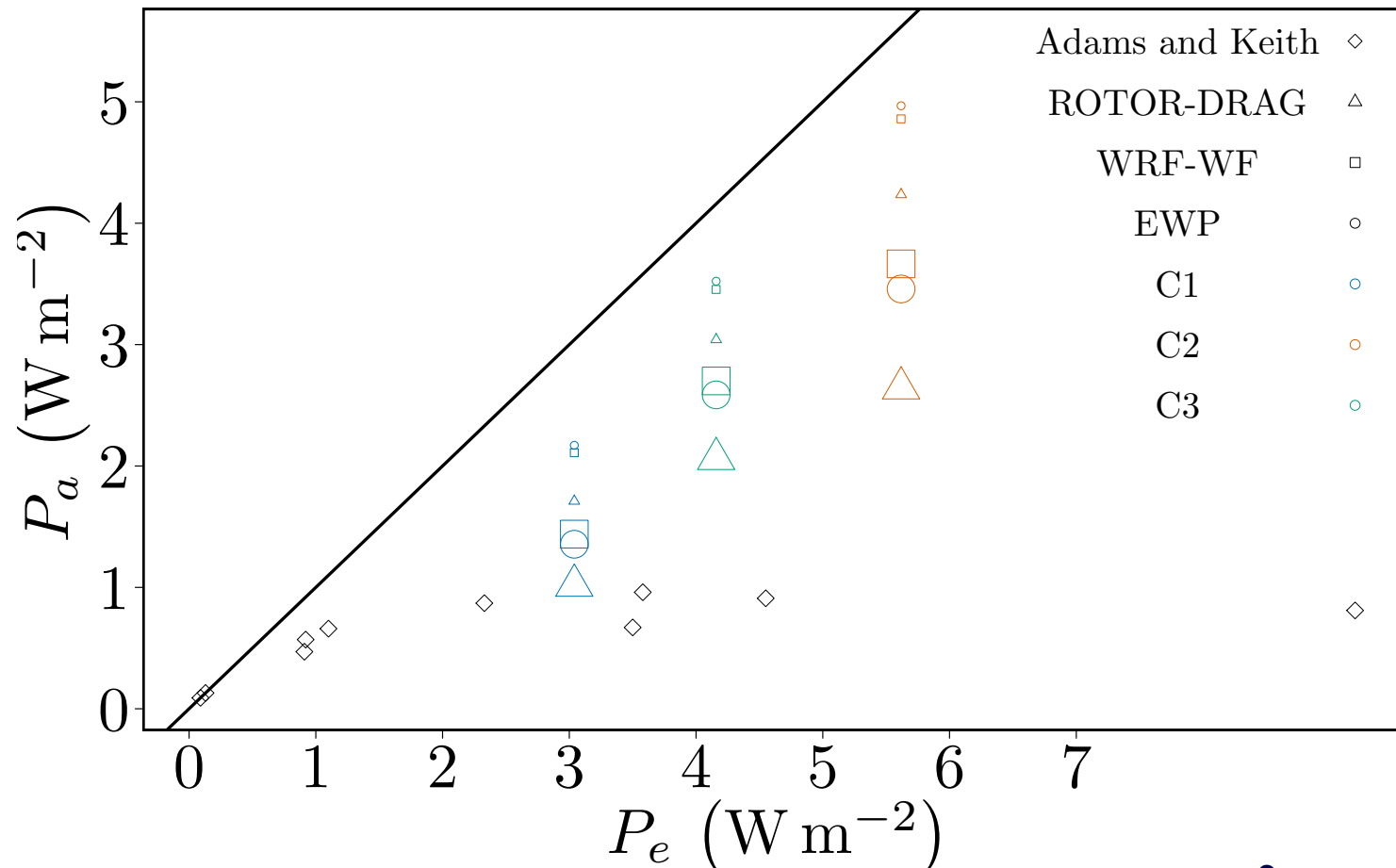


# Results

Dots-size is related to wind farm size

Symbols represent the wind farm parametrisations

Colours indicate the wind climates



- All actual power predictions are larger than  $P_a = 1 \text{ W m}^{-2}$
- Clear (almost linear) dependency on the wind climate
- For C2 climate:  $3.5 \text{ W m}^{-2}$  (100 Turbines) vs.  $2.6 \text{ W m}^{-2}$  (3.600 Turbines)

# Conclusion

- The power density modelled with the mesoscale model is in line with observations ( $3.5 \text{ W m}^{-2}$  for 100 turbines, for the C2 climate (similar to that at HRI))
- The power density is a clear function of the climate  
⇒ Consequently, the study from Adams and Keith is incomplete
- The power density decreases by around 25%, for wind farms 36 times larger than HRI